THE RELATIONSHIP BETWEEN PAIN AND EMOTIONAL FACES: INVESTIGATING THE ROLES OF LOAD AND VALENCE

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ABSTRACT

Page Sloan Dobson: The relationship between pain and emotional faces
(Under the direction of Mark Hollins)

It is well established that pain perception can be decreased when one is completing a cognitive task or exposed to mood enhancing stimuli. However, there is much less research concerning valenced distractors. In this experiment, both stimulus valence and cognitive load were manipulated by presenting emotional faces that were either upright (low-load) or inverted (high-load). Participants viewed the images while experiencing noxious heat pulses and then gave ratings on both the visual and thermal stimuli. Pain intensity and unpleasantness were significantly higher when participants viewed happy faces compared with neutral faces, regardless of orientation. This finding is at odds with studies on emotional modulation of pain, in which pleasant stimuli reduce pain compared with neutral stimuli. However, as both upright and inverted happy faces were recognized with high accuracy, the present findings are in line with distraction studies in which concurrently presented low-load stimuli result in higher pain ratings than high-load distractors. That is, happy faces required much less processing for identification and were thus ineffective distractors compared with the more ambiguous neutral faces. Limitations and future directions are discussed.

This work is dedicated to my family.

To Dad, Mom and Brother John, who have driven me.

Above all, to my husband. I am so thankful to you and for you!

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Introduction

Cognition and emotion both affect pain, with distractions and improved mood serving to reduce pain. In life, one can imagine situations in which these factors work together (being distracted from pain by an activity that lifts your mood, such as playing piano) or against each other (completing a boring, joyless task that is distracting but lowers mood). However, most experimental paradigms manipulate either cognitive or emotional factors and do not consider the ways in which emotional distractors influence noxious processing. The purpose of this study is to test the relationship between these factors in the modulation of pain.

Pain and Distraction

Experimental evidence points to a negative relationship between pain and unrelated cognitive processing, suggesting that these processes share a common pool of resources. Behavioral reports of pain, in response to a noxious stimulus, are reduced during cognitively-demanding tasks such as simple math problems (Dowman, 2004; Schelreth, Baumgartner, Magerl, Stoeter, & Treede, 2003;Terkelsen, Andersen, Molgaard, Hansen, & Jensen, 2004; Yamaki, Kakigi, Watanabe, & Hoshiyama, 2005), Stroop paradigms (Bantrick, Wise, Ploghaus, Clare, Smith, & Tracey, 2002; Seminowicz, Mikulis, Davis, 2004; Valet et al., 2004), n-back tests (Bingel, Rose, Glascher, & Buchel, 2007; Buhle & Wager, 2010), and video games (Campbell, Witmer, Simango, Carteret, Loggia, 2010; Raudenbush, Koon, Cessna, & McCombs, 2009).

Although the majority of experiments report this pattern, some report no effect of distraction (Pud & Sapir, 2006; Roelofs, Peters, van der Zijden, & Vlaeyen, 2003; Van Damme, Crombez, Eccelston, Goubert, 2004). Therefore, not all distractors are effective analgesics. The extent to which a task can reduce pain depends on the amount of load required by the task (Buhle & Wager, 2010; Veldhuijzen, Kenemans, de Bruin, Olivier, & Volkerts, 2006), level of concurrent pain (Buhle & Wager, 2010), and characteristics of the individual (Campbell et al, 2009; Roelofs, Peters, van der Zijden, Vlaeyen, 2004; Seminowicz, Mikulis, & Davis, 2004).

Imaging evidence suggests that these changes in pain, revealed by self-report measures, are accompanied by changes in brain activity. Reduced activity during cognitively-demanding tasks is found in several areas associated with pain processing, including the somatosensory cortices (Seminowicz, Mikulis, Davis, 2004), as well as the thalamus, insula, and the anterior cingulate cortex (Bantick et al., 2002; Valet et al., 2004). Distraction during pain is also associated with increased activation in certain areas including orbitofrontal cortex (OFC), perigenual anterior cingulate cortex (pACC), periaqueductal grey (PAG), & posterior thalamus (Bantick et al., 2002; Petrovic et al., 2000; Valet et al., 2004). Increased activity in frontal areas (OFC, ACC) reported by these studies is thought to reflect top down influences on pain processing.

Pain and Emotion

Laboratory inductions of mood generally find a valence-specific effect on pain ratings. Pleasant stimuli reduce subjective pain ratings or increase pain tolerance while unpleasant stimuli tend to increase pain ratings and decrease pain tolerance. This pattern holds for various stimulus types, including pictures (de Wied, & Verbaten, 2001;

Meagher, Arnau, Rhudy, 2001), videos (Weisenberg, Raz, & Hener, 1998), music (Roy, Peretz, Rainville, 2008), written statements (Zelman, Howland, Nichols, Cleeland, 1989), and odorants (Villemure & Bushnell, 2009; Villemure, Slotnick, & Bushnell, 2003). However, not all studies find this pattern. For example, greater pain in the presence of emotional odorants (Martin, 2006) and emotional faces (Senkowski, Kautz, Hauck, Zimmerman, & Engel, 2011) of both positive and negative valence were found compared to neutral stimuli. Negative mood states, such as fear, have been found to increase pain threshold or tolerance when the emotion is strong enough to produce endogenous opioid release or cardiovascular changes (Rhudy & Meagher, 2000).

As with cognitive tasks, there are brain activation changes associated with pain modulation due to mood induction. Villemure and Bushnell (2009) found that pleasant odorants reduced pain ratings, and that these valence-related changes were associated with decreased activation of the anterior cingulate, medial thalamus, and primary and secondary somatosensory cortices. In another study, anxiety induced by threat of pain increased entorhinal responses, which predicted changes in pACC cingulate (related to affective pain processing) and mid-insula (related to sensory pain processing) to electrical pulses (Ploghaus et al., 2001).

Subjective pain ratings and brain activation patterns are measures of supraspinal modulations of pain. Emotional modulation also occurs at the spinal level. Rhudy, Williams, McCabe, Nguyen, and Rambo (2005) measured both subjective ratings and the nociceptive flexion reflex (NFR), an involuntary measure of nociceptive processing. Although the NFR is considered a more objective measure that is less susceptible to reporting bias than participant pain ratings, it can be modulated by descending influences. Participants viewed images with either positive or negative valence while painful electrical pulses were delivered to their ankle. As expected, subjective pain ratings were higher during unpleasant pictures and lower during pleasant pictures compared with neutral pictures. This measure of supraspinal pain processing was corroborated by the NFR magnitudes; compared with responses to electrical stimulation paired with neutral images, amplitudes were higher during unpleasant pictures and lower during pleasant pictures. Thus, affective stimuli are capable of modulating both spinal and supraspinal measures of nociceptive processing.

Pain, Distraction, and Emotion

Although most experiments focus on either a cognitive or an emotional manipulation, it is difficult to fully dissociate these factors. For instance, a distracting task could be more enjoyable than focusing on the painful heat pulse. If so, any pain modulation could be due to decreased attention, increased positive mood, or a combination of both. It is thus important to consider the possible contributions of both processes in experiments that ostensibly involve only one or the other.

Villemure, Slotnick, and Bushnell (2003) attempted to tease apart the effects of distraction and emotion by directing participants' attention (distraction) to either painful heat pulses or to odorants that were either pleasant or unpleasant (emotion). Participants rated the noxious heat pulses on two components of pain, intensity and unpleasantness. A double dissociation was found, such that distraction reduced pain intensity (regardless of odor valence) while odor valence affected pain unpleasantness (regardless of attentional focus). Sloan & Hollins (under review) tested the generality of this double dissociation by replicating Villemure et al. with affective sound clips in place of odorants. Using auditory stimuli, this pattern of results did not hold. Pain unpleasantness was affected by both the direction of attention and sound valence, while pain intensity ratings were impervious to the experimental manipulations.

In neither study did the effects of emotion and attention on pain ratings interact. The attentional manipulation in both studies ostensibly compared two extreme conditions: Instructions asked subjects to focus their attention exclusively on the pain, or exclusively on the distracting stimulus. Additionally, neither study asked participants to attend to the valence of the distractor, but instead to the physical intensity of the odorant or sound. It may be that the emotional value of the distractor modulates the analgesic effectiveness of the distractor when the participant is asked to attend to both the pain and the emotional content of the distractor concurrently. The present study tests this hypothesis using emotional faces as the distractor.

Faces are an especially good fit for this line of research for several reasons. First, some types of stimuli may be more arousing or novel to particular groups of people. Emotional human faces on the other hand are much less susceptive to individual bias because most individuals come into contact with an emotional human face every day. Because the average person is a face expert, there may be less variance in how these images are processed compared to images of physical injuries. Second, interpreting emotions is especially important to us as a means of social connection and, from an evolutionary standpoint, survival.

Along with their validity outside the laboratory, faces are also excellent candidates for experimental manipulations. One reason is that a wide variety of emotions can be represented with few physical differences. A neutral face shares many more visual features with emotional faces than a neutral scene (such as a grocery store) does with an emotional scene (a mountain view or dirty restroom).

Similarly, we are able to manipulate attentional load without changing any physical features by simply inverting the face. Yin (1969) first reported a disproportionate reduction in memory for inverted faces compared to other inverted images, a finding called the face inversion effect (FIE). Many studies have since replicated the poor memory for inverted faces (reviewed by Valentine, 1988). Other types of task performance such as visual search for singletons (Lamy et al., 2008) are also disrupted or slowed by inversion. As these studies show, it is more difficult to process inverted versus upright faces. For this reason, face orientation is used as a proxy for cognitive load in the studies described below. That is, upright faces are considered low-load and inverted faces are considered high-load. In the context of the current experiment, this manipulation allows us to determine if the effects of distractor valence on pain differ between high-load versus low-load conditions, instead of merely comparing load and no load conditions.

Additionally, human faces display a wide array of expressions which can be categorized further than simply “pleasant” or “unpleasant”. Although sounds, odorants, and other visual stimuli are capable of influencing many emotions, the delineation of which emotions are intended or experienced may be less clear. Using as an example an image of a mutilated body, it is reasonable that one may feel disgusted, sad, angry, and fearful, but all of these emotions are collectively called unpleasant in the experimental setting. Conversely, the images used in this experiment are designed to clearly represent just one emotion, making it easier to determine which specific emotions are responsible for the effects of valence. The fact that information about emotions is actually present in a facial expression (whereas it is not in, say, a sunset) makes it possible to objectively measure a person's ability to correctly perceive emotions.

Finally, faces are prime candidates for pain modulation based on their degree of arousal. The effectiveness of other emotional stimuli in influencing pain relies on both their valence and the arousal they produce (Rhudy, Williams, McCabe, Russell, & Maynard, 2008). The expressions used in these experiments (happy, angry, fearful) are rated as moderately to highly arousing (Gerber et al., 2008).

Effect of viewing emotional faces on pain

Despite the suitability of faces for pain research, there are surprisingly few experimental studies on the impact of emotional faces on pain ratings. Most often, studies of faces and pain are investigating vicarious pain by presenting subjects with images or videos of other people expressing pain. Vicarious pain studies usually find that viewing pain faces increases reports of one's own pain in response to a noxious stimulus (Mailhot, Vachon-Presseau, Jackson, & Rainville, 2008). Additionally, brain activations while viewing someone else in pain are similar to those observed when the subject is in pain (Botvinick, et al., 2005; Vachon-Presseau et al., 2010). However, there are relatively few studies that investigate how emotional, but not pained, faces modulate the experience of one's own pain. This paucity of studies is surprising because faces provide an excellent stimulus, as described above.

Senkowski et al. (2010) presented noxious electrical pulses either alone or with a face and asked participants to rate the unpleasantness of the shock. The actor in the pictures conveyed happiness, anger, fear, or a neutral expression. Faces with a negative emotion increased pain ratings compared to neutral expressions and to electrical pulses presented alone. This result follows the literature reported earlier where unpleasant stimuli increase pain. Interestingly, pain responses to happy faces also increased pain compared with neutral faces or no face- a finding that runs counter to most other emotion studies. Additionally, neutral faces compared to the no face trials raised pain ratings.

Two experiments conducted by another research group found a different pattern of subjective pain rating modulations by faces displaying positive and negative expressions. In both a fMRI study (Yoshino et al., 2010) and a MEG study (Yoshino et al., 2012), painful electrical pulses were delivered through an electrode needle that was inserted just below the skin while sad, happy, or neutral faces were viewed. Pain ratings were higher during sad faces than happy and neutral faces, with no differences between happy and neutral faces.

Reicherts, Gerdes, Pauli, and Wieser (2013) played videos of models making facial expressions (neutral, joy, fear, or pain) while participants felt noxious heat pulses. Pain intensity ratings were lower for all videos compared with only a fixation cross on screen, an effect attributed to distraction. Videos of transient pain expressions by the model were associated with the highest pain ratings, an effect that corroborates studies of vicarious pain increasing experienced pain (Mailhot et al., 2008). There were no differences between the pain intensity ratings in the presence of neutral, joy, or fear videos.

The studies reported above are equivocal regarding the effects of emotional, but not pained, facial expressions on pain perception, with (1) a valence-specific effect such that only the negatively-valenced expression increased pain ratings (Yoshino et al., 2010; 2012), (2) valence-general increases in pain (Senkowski et al., 2010), and (3) no effect of emotional expressions on pain (Reicherts et al., 2013).

These differing effects of emotional modulation of pain is surprising given evidence from emotional priming research showing that the appraisal of faces can influence our affective interpretation of other stimuli. For instance, Chinese characters are rated as more pleasant by those unfamiliar with the language when they follow a likable face (preferred presidential candidate) than when they follow a disliked face (non-preferred candidate; Payne, Hall, Cameron, & Bishara, 2010). Using a similar paradigm, Blaison et al. (2012) found that Chinese characters were rated as more anger- or fear-evoking following angry and fearful faces, respectively.

One possible explanation for the disparity in those results and that of other emotional stimuli is that viewing emotional faces may not evoke the first person experience of said emotion when the participant is experiencing a contrasting emotion. For instance, viewing a happy face may decrease, instead of increase, positive affect in the participant when the participant is in pain. However, if this were the case, we would expect that the studies listed above would have been more similar to Senkowski's results. It is also difficult to support this theory by discussing previous research as there has not been a paradigm to date that assesses the emotional reaction of a participant in pain to emotional faces made by others.

Two other explanations for why this valence-specific pattern has not emerged in the literature on emotional faces and pain research are easier to assess given the experiment paradigms. First, timing may be important. In both Senkowski and Yoshino, the faces were presented concurrently with a painful shock. Perhaps faces must be presented first to influence pain, much like the set up for the emotional priming in Payne's studies. Secondly, emotional faces may only be capable of influencing the affective component of pain, not the sensory (intensity) component. All three studies cited above didn't discriminate between the two, so conclusions cannot be drawn regarding this possibility.

A cognitive, instead of emotional, approach may be necessary to explain these results, considering the lack of control for general effects of attention. In both Senkowski et al. and Reicherts et al., the only controls for the appearance of faces were fixation crosshairs, while in Yoshino et al. there were no trials without faces. This lack of a control for an on-setting stimulus is an especially strong argument of Senkowski's study, were neutral faces raised pain ratings compared with a trials were pain was presented without a visual stimulus. This increase study could be due to an arousing or orienting effect such that the appearance of a face (a complex, socially important cue), compared with a crosshair (meaningless and visually simple), induced participants to direct more resources to all aspects of the experiment, including the pain stimulus (another evolutionarily important signal). In Reicherts's experiment, all videos of transient facial expressions reduced pain compared to a fixed crosshair. This design speaks more to the effectiveness of videos to distract an individual from a pain than it does about the specific emotion conveyed in the video. Based on these differences, the orienting hypothesis posits that differences in stimulus presentation are at least partially responsible for the divergent findings.

Upright and inverted faces

Cognitive processing. Many investigations of emotional face processing use inverted faces as controls for physical qualities of the face (Bannermann, Milders, de Gelder, & Sahraie, 2009; Eastwood. Smilek, Merikle, 2001; Fox & Damjanovic, 2006; Lamy, Amunts, Bar-Haim, 2008; Williams, Moss, Bradshaw, & Mattingley, 2005). Such a control is necessary because the effect of emotion could be due to differences in the distinctiveness of facial features varying across emotions (whites of the eyes, teeth visibility, brow contours) or low-level visual differences (luminance, energy, texture, contrast). Calvo and Marrero (2009) found that the emotional faces with the greatest visual search advantage also had the greatest number of distinct physical features such as wide open eyes, lips apart, and forehead wrinkles, but that the low-level visual qualities were unrelated to search efficiency. The use of inverted faces as controls holds facial features and physical characteristics constant, while presumably changing the speed of image processing or way the image is processed.

There are two explanations for different task performance when faces are inverted: 1) inverted face processing is a different process than upright face processing; 2) inverted and upright faces use the same process, it is just slower and more effortful for inverted faces. Farrah et al. (1995) conducted some of the early work in support of the former.

Gathering emotional information from a human face is an expert process for most, one that we do every day. Although this process may feel automatic, evidence that emotional processing does require cognitive resources comes from studies showing that attentional demands from a secondary cognitive task reduce the effects of emotional faces (Ethral et al., 2005; Okon-Singer et al., 2007).

However, the cognitive demands of emotional processing are low. In the lab, humans can reliably identify emotional expressions when they are shown for only 100-150 ms (Calvo & Marrero, 2009; Esteves & Ohman, 2008). ERPs show very early modulations in response to emotional versus neutral faces (Eimer & Holmes, 2002; Eimer & Holmes, 2007). Emotional faces grab attention even when they are task irrelevant, as seen by slower singleton identification (Hodsoll, Viding, & Lavie, 2011), increased attentional blink (Bach, Schmidt-Daffy, & Dolan, 2014), and slower reaction times in a spatial cueing task (Okon-Singer, Tzelgov, & Henik, 2007). These incredibly fast emotion effects due to emotional faces suggest that processing the emotion on a human face is a low-load task. Therefore, when there is no attempt to modulate attention or perform another task, upright emotional faces provide an excellent way to test the effects of emotion with little consumption of cognitive resources.

Emotional processing. Several paradigms, including emotional priming of popout (Lamy et al., 2008) and threat biased saccades (Bannermann et al., 2009), show differential task performance due to valence for upright, but not inverted, faces. Findings such as these are interpreted as evidence that the effects are due solely to the emotionality of the face and not to any featural or low-level visual differences between the faces.

However, experiments that investigate the effects of orientation on emotional face processing suggest that inversion effects are not always present in behavioral and neuroimaging measures. Using the same battery of faces that were used in the current experiments, Lipp, Price, and Tellegen (2009) found no effect of inversion on detection times in visual search for emotion, or on measures of explicit and implicit evaluations of the expressions of the faces.

Bannerman et al. (2008) found that accuracy was better for upright versus inverted emotional faces. However, the accuracy for recognizing the target expression in the inverted condition was still at approximately 80% and there were no differences in response times between upright and inverted faces. Lamy et al. (2008) found no inversion effects on visual search for an emotional singleton in either accuracy or reaction time measures. Emotional information can still be gleaned from inverted faces, even though it is often slowed and less accurate compared with upright face processing.

The finding that inversion does not totally prevent identification of facial expressions is not surprising given the findings on featural processing in inverted faces and upright emotional faces. Inverted face processing relies more heavily on features, not holistic information, than upright face processing (Farah, Tanaka, & Drain, 1995; Searcy & Bartlett, 1996). Calvo and Marero (2009) found that specific facial features played a role in the effects of emotion on visual search performance. Therefore, it is reasonable to expect that information about the emotion displayed on inverted faces can be gathered by certain features (such as raised brows, visible teeth, etc).

Once an expression has been recognized, it has the potential to influence later processing. It just may take longer for these influences to manifest because it takes longer to recognize emotion from an inverted face.

Pain modulation is an excellent vehicle to test the theory that upright and inverted faces have the same qualitative effect on later processing. It is well established that emotional stimuli can influence pain ratings, but this study will seek to determine if the additional cognitive load of inverting faces will interact with the emotional modulation. Speeded manual responses and ERPs that are elicited less than a second after stimulus presentation may be more sensitive to the effects of inversion, whereas the slower identification of inverted facial expressions may still have time to influence perception of a noxious heat pulse lasting 4s. Therefore, it is not unreasonable to suspect that there could be emotional modulation of pain even with inverted faces. Including upright and inverted faces allows conclusions to be drawn about the effects of emotion and distraction on pain perception, as well as on the extent of emotional information available from inverted faces.

Pain modulates emotional reactions to valenced stimuli

The focus of most pain studies is on factors that modulate pain, with the end goal of applying the findings of the research to reduce suffering in those with acute and chronic pain. Often, the effect of pain on the task at hand is overlooked. In order to fully understand the forces that interact with the processing of noxious stimuli, it is important to understand both directions of the relationship. Anecdotally, pain is known to lower mood and disrupt cognition, observations that have experimental support. Pain has been shown to reduce performance in a cognitively demanding task (Bingel et al., 2007;

Buhle & Wager, 2010). Emotional decision making, along with these cognitive failures, is also disrupted by pain (Apkarian et al., 2004).

Several experiments have demonstrated the ability of pain to modulate emotional processing. Godinho and colleagues (2008) compared valence ratings to images during painful electrical shocks versus innocuous vibrations. The images were taken from the International Affective Picture System database as well as from other sources. The variety of pictures included scenes (e.g., pleasant: waterfalls, unpleasant: car accidents), objects (e.g., pleasant: sports cars, unpleasant: guns), or humans (e.g., pleasant: erotic, unpleasant: suicide attempts). Each block contained 3 pictures matched on valence (pleasant, unpleasant, or neutral). Blocks of pleasant images were rated as significantly less pleasant during pain conditions than non-pain conditions. Ratings of unpleasant and neutral blocks did not differ between pain conditions.

Although Godhino's stimuli were not exclusively images of faces, faces were included in the images of the human body. Gerdes, Wieser, Alpers, Strack, and Pauli (2012) investigated the influence of pain on the valuation of faces in particular. Valence and arousal ratings of emotional faces were not changed when the face was paired with a painful pressure stimulus.

Gerdes et al. also recorded facial EMGs made in response to the pictures. Participants were told to either make a compatible face (e.g., smile in response to a pleasant expression) or an incompatible expression (frown in response to a pleasant expression). Pain slowed both the compatible and incompatible facial movements to happy faces, but did not affect facial movements in response to unpleasant expressions. Although this study did not find the overt rating differences that Godhino found, both studies found that pain only disrupts processing of positively valenced stimuli.

In another study (Wieser, Gerdes, Greiner, Reicherts, & Pauli, 2012), this research group investigated how pain affects facial processing using ERPs, instead of EMGs. Again, there were no differences in affective ratings between faces viewed during a painful versus non-painful pressure stimulus. Corroborating the behavioral ratings, there were no pain- related differences in ERPs that reflect affective facial processing (N170, EPN). However, pain did disrupt measures of attention to faces at both early (P100) and later (LPP) stages.

It seems from the studies reported thus far (Gerdes et al., 2012; Reicharts et al.,2013; Wieser et al., 2012) that pain does not change our ability to recognize the strength (arousal) or value (valence) of emotional faces. Although this categorization of facial expression seems impervious to the effects of pain, our reactions to the faces (Gerdes et al.) and attention allocated to facial processing (as indexed by ERPs in Wieser et al.) are modulated by pain.

CURRENT STUDIES

The purpose of the main experiment is to investigate how emotional faces modulate the experience of pain by comparing the effects of emotional expression (neutral, happy, angry, fearful), cognitive load (low-load: upright faces, high-load: inverted faces), and the joint effects of affect and distraction on two components of pain (intensity and unpleasantness).

The experimental design allows for a test of facial expression by comparing pain ratings made while viewing a neutral face to those made while viewing the other expressions. This design controls for two possible cognitive effects. First, any orienting effects of an on-setting visual stimulus are controlled for by the inclusion of a scrambled face condition. Secondly, the comparison between upright and inverted faces is meant to test the extent to which the cognitive load required to identify emotional faces contributes to the modulation of pain by those stimuli. We must first make sure that emotional information can be gleaned from inverted emotional faces to ensure that differences are not due to a difference in available emotion information. It is also important for the study aims that it is more difficult to identify an emotion on an inverted versus an upright face. That is, emotion recognition accuracy should be lower for inverted compared with upright faces and participants will have to expend more cognitive effort for inverted, than upright faces. Toward that purpose, a pilot study was conducted to determine the stimulus presentation time need to extract emotional information from both upright and inverted faces with an accuracy level of at least 85% for both orientation conditions, with upright faces having a significantly higher accuracy rating.

Pilot Study

The purpose of this study is to shed light on how long it takes for emotional information to be gleaned from an inverted face. This study seeks to equate emotion identification accuracy between upright and inverted faces by adjusting the amount of time the faces are viewed by participants. Results of this study will determine the duration of face presentation in the main experiment.

Method

Participants

Twenty nine subjects were recruited through the Psychology Research Participant Pool and enrolled in the study. Participants were excluded from participation if they had a mood disorder or if their vision was not normal or corrected to normal. The first participant was deemed a practice subject and their data is not included in the analysis. The remaining 28 participants (20 females) were between 18 and 25 years of age (*M*=18.5, *SD*=.5). The experimental procedure was explained and written informed consent was obtained before participation.

Materials and Procedures

***Visual Stimuli*.** Faces were selected from the Facial Expressions of Emotion: Stimuli and Tests (FEEST; Young, Perret, Calder, Sprengelmeyer, Ekman, 2002) picture library. The images to be used in this study are taken from the Ekman 60 Faces subset of the FEEST database. This subset includes black and white photographs of 6 females and 4 males portraying neutral, angry, disgusted, fearful, happy, sad, and surprised facial expressions. These images were chosen for inclusion in the Ekman 60 Faces subset because the models' expressions were the best recognized within the FEEST database, based on accuracy in a forced choice recognition test.

This experiment included happy, angry, fearful and neutral faces from 5 female and 4 male models. Original images were cropped so that only the face is visible, by removing hair and the surrounding background from each image. All pictures were also inverted after cropping.

***Questionnaires*.** Participants completed two pen and paper questionnaires. The Demographic Information sheet asked the participant to report age, gender, ethnicity, race, and dominant hand. Although the recruitment advertisement stressed that those with mood disorders were ineligible for this study, The Beck Depression Inventory-II (BDI-II; Beck et al., 1996) was administered as a further screening tool, as those with depression have deficits in emotional face processing (Fales et al., 2008; Leppanen, 2006).This survey asks participants to answer 21 questions concerning their emotional health. Information concerning on-campus emotional support resources was given to participants both at consent and debriefing.

Pilot Task

The pilot task was administered after the questionnaires. There were 5 experimental blocks. In each block, a series of visual (upright or inverted faces) and auditory (500 Hz pure tone) stimuli were presented concurrently. Participants were instructed to maintain attention on the computer screen, even in the absence of a visual stimulus, as they must provide feedback concerning the expressions on the faces. While there are no faces onscreen, participants were instructed to fixate on a cross that was on the computer screen at all times (except when a face is onscreen). When a face appears onscreen, participants were instructed to attend to the face and were free to move their eyes around the face in order to determine the expression on that face.

Trials were separated into blocks by the amount of time that the visual stimuli were onscreen. There were five experimental blocks: with faces onscreen for 500ms, 750ms, 1000ms, 1500ms, and 2000ms. That is, all trials in each block included visual stimuli that appeared for the same amount of time (e.g. 500 ms).

In each block, there were 72 trials. Each facial orientation (upright and inverted) was presented 36 times in each block. In each block, the 9 models appeared 8 times: displaying neutral, happy, angry, and fearful expressions both upright and upside down. Order of presentation was randomized within each block. Block presentation order was counterbalanced across participants.

In order to simulate the distraction from a different modality that will accompany and follow faces in the main experiment (i.e. heat pulses), an auditory stimulus was paired with the visual stimuli on each trial. A 500 Hz pure tone onset with the visual stimulus and lasted for 4s, regardless of how long the visual stimulus was onscreen. The tone was presented over headphones at approximately 60 dbSPL.

Immediately following the offset of the auditory tone, the participant was required to make a 4-alternative forced choice (4-AFC) judgment concerning the emotion on the face. The participant clicked one of four buttons onscreen (neutral, happy, angry, fearful) to make their choice for each trial. Instructions were given for the participant to make the decision as quickly as possible, but there was no time limit for the decision. The next trial began 5s after the participant made their choice.

When participants completed the experimental task, they were thanked for their participation and debriefed as to the purposes of the study. Credit was assigned within 24 hours of participation.

Results

Questionnaires

The BDI-II was administered to determine whether the current mood state of the participant would be related to the ability to make emotional judgments of the visual stimuli. Participants indicated the severity of 21 symptoms and the total score was calculated by summing all responses such that a higher score indicates more severe depression. A score between 0-13 indicates minimal depression, and all participants in this study scored 12 or below (M=3.29, SD=3.59). Due to the low scores and the fact that this predictor was not significant in the initial model, F (1, 26) = .70, p=.4092, it was dropped from the final model.

Accuracy

Accuracy data was collected and analyzed for the 4-AFC response concerning facial expression for each block. The primary measure of interest is the accuracy difference in the upright and inverted expressions for each block or stimulus duration. A repeated-measures general linear mixed model (GLM) was conducted using stimulus duration, image orientation, and facial expression to predict emotion judgment accuracy, with participants as random intercepts. *Figure 1* shows the proportion correct for each facial type across the five presentation times.

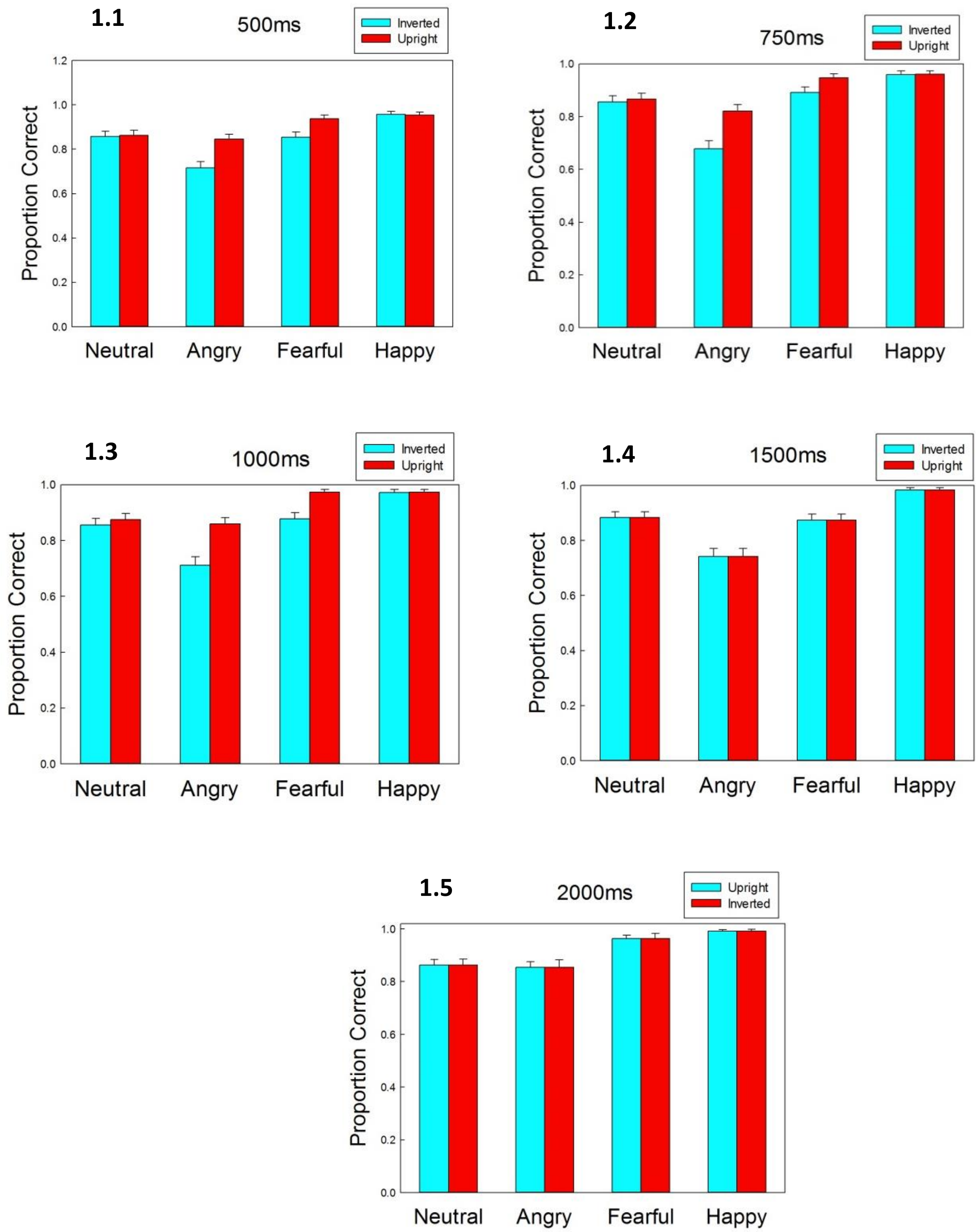

Figure 1. Proportion correct in the expression categorization task by orientation and facial expression when the image was presented for 500ms (1.1), 750ms (1.2), 1000ms (1.3), 1500ms (1.4) and 2000ms (1.5).

There was no effect of main effect of stimulus duration on emotion judgment accuracy, $F(4, 100) = 1.87$, $p=.1214$ and no interaction of stimulus duration with either orientation, $F(4, 100) = 0.25$, $p=.9105$ or expression $F(12, 300) = 0.68$, $p=.7734$.

There was a main effect of image orientation $F(1, 27) = 76.08$, $p<.0001$, such that inverted faces ($M=.857$, $SE=.009$) were significantly less accurate overall than upright faces ($M=.9125$, $SE=.009$).

There was a main effect of facial expression $F(3, 81) = 163.58$, $p<.0001$. Post-hoc testing with Tukey's adjustment shows that angry faces had significantly lower accuracy than fearful $t(81)$, -15.24, $p<.0001$, happy $t(81)$, -21.07, $p<.0001$, and neutral $t(81)$, -8.79, $p<.0001$ faces. Neutral faces were less accurately recognized than fearful $t(81)$, -6.35, $p<.0001$ and happy $t(81)$, -12.11, $p<.0001$ faces, while fearful faces were not recognized as well as happy faces $t(81)$, -5.77, $p<.0001$.

Discussion

The purpose of the pilot study was to determine whether emotional information could be gleaned from inverted faces and to establish the stimulus timing for the main experimental task. Overall accuracy was higher for upright compared to inverted faces, which was to be expected because processing inverted faces has proven more difficult in many other tasks (Lamy et al., 2008; Valentine, 1988; Yin, 1969). However, accuracy for inverted faces was still very high, at 85.7% overall.

Interestingly, the small, but significant inversion effect did not differ across experimental blocks. Accuracy for upright faces was not significantly higher when faces were presented for 2000ms ($M= .92$, $SD=.28$) compared with 500ms ($M= .90$, $SD=.3$).

This result is not surprising as previous research has shown the very fast recognition (Calvo & Marrero, 2009; Esteves & Ohman, 2008) and effects (Blaison et al., 2012; Payne, et al., 2010) of upright emotional face processing. What is surprising is that emotional recognition is so high for inverted faces at both long (*M*= .87, *SD*=.34) and short (*M*= .85, *SD*=.36) presentation times. Together, these results indicate that emotional information can be gleaned from inverted faces very quickly, but that it is a less accurate, and thus more difficult, process than when the face is upright.

Since the goal is to analyze the effects of emotion and cognition, it is important that recognition of the faces is sufficiently high and that the visual stimulus is sufficiently distracting. Since there were no differences in accuracy across block timing, it seems that emotion recognition is sufficiently high regardless of the stimulus duration. However, there are still several reasons to leave the visual stimulus on-screen for as long as possible. First, it is important that the emotions on the faces are recognized if they are to have a significant effect on pain ratings. Although there were no significant differences, the trend was for higher accuracy at longer stimulus durations. This is especially important so that inverted faces have the best chance for emotional identification. Secondly, since we are interested in the distracting effects of the visual stimuli, it is important that the faces overlap with the heat pain stimulus, which takes time to reach the destination temperature. At short presentation times, participants could attend to the face and then shift their attention to the heat pulse only after the face had disappeared and the thermode had reached a noxious temperature. In that case, we should not expect to see any cognitive effects. For these reasons, the visual stimulus will onset with the heat pulse and will last 2000 of the 4000ms duration of the heat pulse on each trial of the main experiment.

Main Experiment

Method

Participants

Potential subjects were recruited through the Psychology Research Participant Pool. Exclusion criteria included any chronic pain disorders, current damage or injury to the right arm, diabetes, or a mood disorder. No potential participants met any of these criteria. Participants were between 18 and 25 years of age and had normal or corrected to normal vision. Sixty undergraduate students gave consent to participate and were enrolled in the study. The first two participants were designated practice subjects and their results are thus not included in the analysis. Data for five of the enrolled subjects could not be collected due to equipment, software, or technical malfunctions. Two subjects rated the heat pulses above the cutoff (over 90 on a 100 point scale) on the first block which immediately ended their participation and resulted in no data from those subjects. Of the remaining 51 remaining subjects, 11 were dropped from analysis because they did not report the necessary level of pain (an average pain rating of 10/100 for the heat pulses with the highest temperatures). The final sample consisted of 39 participants (24 females) between the ages of 18 and 25 (M=19.1, SD=0.97). However, not all experimental blocks were included for every participant. Two participants rated above 90 on the last experimental block; that block was immediately terminated and was not analyzed. Data from two additional blocks (from two different participants) were not available for analysis due to a software failure that occurred during those blocks. The experimental procedure was explained to all participants and written informed consent was obtained. All aspects of the study were approved in advance by the Institutional Review Board of the University of North Carolina at Chapel Hill.

Materials and Procedures

Visual Stimuli*.* Faces in the main experiment were identical to the ones used in the pilot experiment, with the addition of scrambled images. Scrambled images were created using each actor's neutral expression and were scrambled by Fourier phase transformation, as in Calvo, Fernandez- Martin, Nummenmaa (2014). This image processing technique randomly rearranges all pixels in the image, but does not change the properties of the pixels. The resulting image therefore has the same size and physical features as the original image, but is no longer recognizable as a human face. In sum, the happy, angry, fearful and neutral faces of the 8 models were cropped and presented both upright and inverted, while the neutral faces of each actor were scrambled by pixel. The resulting image types, upright, inverted, and scrambled, are necessary to answer the questions that have motivated this study.

Questionnaires*.* Participants completed three pen and paper questionnaires after giving informed consent. The Demographic Information Sheet asked the participant to report age, gender, ethnicity, race, and dominant hand. The Current Pain Questionnaire asked the participant to rate the intensity and unpleasantness of their pain over the past two weeks and at the time of testing. The Patient Health Questionnaire (PHQ-9;Kroenke, Spitzer, & Williams, 2001) assessed the mood state of the individuals. Although the recruitment advertisement stressed that those with mood disorders are ineligible for this study, the PHQ was administered to further screen for depression. Information concerning on-campus emotional support resources were given to participants both at consent and debriefing.

***Pain Threshold Determination*.** Following the questionnaires, pain thresholds were determined. Heat pulses were delivered using a Medoc Neuro Sensory Analyzer Model TSA-II. This apparatus creates painful heat pulses by applying a contact thermode to the participant's skin. The 1.6 cm^2 thermode reaches the destination temperature at a rate of approximately $5^oC/s$. Temperature control is achieved using Medoc software to determine pain threshold and a LabVIEW (National Instruments Version 2014) program during the experimental task.

Heat pain threshold was determined for each participant using the method of limits. Heat ramps were delivered to the volar forearm using the contact thermode. Starting from an adaptation temperature of 35^oC, four successive ramps were delivered at a rate of $2^oC/s$. Participants press a button when the heat becomes painful. Between ramps there were a 30s delay and the thermode was placed on a different area of the forearm for each trial. Thresholds were determined by averaging these four trials.

VAS practice. Following heat pain threshold determination, participants practiced using the VAS to rate intensity and unpleasantness. Subjects practiced making intensity and unpleasantness ratings on a visual analogue scale (VAS) in response to sound clips. Participants heard 4 different sound clips from the International Affective Database of Sounds (IADS; Bradly and Lang, 2007), each lasting 4s. Two sounds were rated as highly unpleasant sounds and two sounds were mildly unpleasant, according to the normative ratings from the database. One sound of each valence category (highly and mildly unpleasant) was presented at a high intensity (software volume setting = 80) and the other two sounds were presented at a low intensity (software volume setting = 50). After hearing each sound, the participant rated the intensity (in terms of loudness) and unpleasantness by using the mouse to fill in a VAS for each factor. Each VAS was in the shape of a rectangle presented on the computer screen. The participant moves the mouse until the length of a red bar within the VAS represents how intense and pleasant/unpleasant they found each sound. The two scales were presented together onscreen. The top scale was the intensity scale, anchored by No Sound and Most Intense Sound Imaginable. The bottom scale was the unpleasantness scale, anchored by Not at all Unpleasant and Extremely Unpleasant.

Experimental Task*.* The main experimental task was administered after VAS practice. A series of 4s heat pulses were presented either alone or with a 2000ms visual stimulus (upright, inverted, or scrambled faces). Heat pulses and visual stimuli had the same onset. Participants were instructed to maintain fixation on the computer screen, even in the absence of a visual stimulus. Participants were instructed to attend to the heat pulses and the visual stimuli, as they would rate both stimuli after each trial.

There are 10 types of trials (heat alone, heat with each upright facial expression, heat with each inverted facial expression, and heat with a scrambled image). Each type was presented 9 times for a total of 90 trials. These trials were grouped into 3 experimental blocks of 30 trials each.

Within each block, each trial type was presented twice in random order. Across all blocks, the 9 models appear 9 times (displaying a neutral, happy, angry, and fearful expression both upright and upside down as well as scrambled). Individual models appear twice in each block, once upright and once inverted. The upright and inverted face of each actor do not have the same expression within a block. The neutral expression of each actor was scrambled. Two actor's scrambled neutral images appear in each block. This is done to control for the physical qualities of the stimuli as these scrambled images are not recognizable as faces. Order of presentation was randomized within each block.

Heat pulses were presented to 10 different sites on the volar forearm. Sites measured $2cm^2$. There were two rows of stimulation sites. Each row included 5 stimulation sites. All sites were measured with a ruler and marked with a skin safe, washable makeup pencil before the task began. Each site on the forearm was stimulated twice per block. Each site was stimulated once before any site was stimulated again and no site was stimulated in two consecutive trials. Order of stimulation was pseudo-randomized for each of the 3 blocks for every subject to meet the stipulations above. There were 2 minute breaks after the first and second blocks, and the experiment concluded after the third block.

Heat pulses were delivered at either 1^oC or 3^oC above pain threshold or 2^oC below pain threshold. Presenting two noxious temperatures along with an innocuous temperature was meant to discourage participants from giving every heat pulse the same intensity and unpleasantness ratings. All heat pulses were 4s in duration with approximately $5^oC/s$ ramp time. The thermode were placed on the skin prior to the initiation of the heat pulse to adapt the skin. The adaptation temperature is 36^oC and lasted approximately 2s.

Following every heat pulse, two visual analogue scales appeared onscreen. The top VAS was pain intensity (anchored by No Pain and Most Intense Pain Imaginable) and the bottom was pain unpleasantness (anchored by Not at all unpleasant and Extremely Unpleasant). Participants made intensity and unpleasantness ratings for the heat pulse delivered on the preceding trial. There was no time limit for participants to make these ratings. Following the VAS ratings, the participant then indicated which emotion was present on the face by selecting one of five buttons (No Face, Scrambled Face, Happy, Angry, Fearful, Neutral). There was no time limit to make the decision concerning the face and the next trial began 5s after the judgment had been made. When participants have completed the experimental task, they were thanked for their participation and debriefed as to the purposes of the study. Credit was assigned within 24 hours of participation.

Results

Heat Pain Thresholds

Before the task began, heat pain thresholds were determined for each participant. Thresholds were used to determine the temperatures used in the main experimental task. This individualization was necessary because pain thresholds are highly variable across individuals and the goal was to create a moderately painful experience for each participant. Heat pain thresholds in our study show variability across individuals with a range from 42 to 47^{o}C (M=44.23, SD = 1.59).

VAS Practice

In order to become familiar with the rating system employed in the main experimental task, participants first practiced using the VAS to rate the intensity (loudness) and unpleasantness of four different sounds. Participants rated the two sounds that were presented at a higher volume by the software (M=23.49, SD=18.33) as significantly more intense than the two sounds that were presented at a lower volume (M=14.00, SD=18.15), $F(1,156) = 11.9$, p=.0007. Participants also rated the sounds with the lower normative pleasantness ratings as more intense (M=21.96, SD=18.31) than those with higher normative pleasantness ratings (M=15.53, SD=18.83), $F(1,156) = 5.48$, p=.02. However, these main effects are qualified by an interaction of sound volume and pleasantness ratings $F(1,156) = 5.48$, p=.02, such that the differences in intensity for sound volume were only significant when the sound was highly unpleasant. Participants rated the two sounds that had lower normative IADS pleasantness ratings as significantly more unpleasant than the two sounds with higher normative pleasantness ratings, $F(1,156) = 4.31$, p=.04. Unpleasantness ratings did not depend on the volume of the sound, $F(1,156) = 3.82$, p=.052, or the interaction between pleasantness and volume, $F(1,156) = 2.79$, p=.10. These results indicate that the participants were able to dissociate intensity and unpleasantness components of each sound and to use the scales to accurately rate each component.

Questionnaires

The Current-Pain Questionnaire (CPQ), given prior to the delivery of any noxious stimuli, assessed the intensity, unpleasantness, and location of any ongoing pain that subjects were experiencing. Separate 0-100 numerical rating scales were used to obtain the intensity and unpleasantness measurements, and subjects indicated on a checklist where on their body any ongoing pain was located. Average pain intensity (*M*= 3.9, *SD*=8.09) and pain unpleasantness (*M*=2.96, *SD*=6.58) ratings were low and no participants reported current pain in their left arm. Most subjects gave negligible ratings of pain intensity (Median=0, Mode=0) and unpleasantness (Median=0, Mode =0), although 5 participants had current pain intensity levels of 20 or more. As current pain intensity was not a significant predictor of pain intensity, pain unpleasantness, or emotional judgment accuracy and as no participant indicated pain in the left arm, current pain levels are not responsible for the results reported below.

The Patient Health Questionnaire was administered to determine whether the current mood state of the participant would be related to the ability to make emotional judgments of the visual stimuli. Participants answered a number of questions on a Likert scale and the total score was calculated by summing all responses. The average total was low (*M*= 2.45, *SD* = 3.11) and is below the total score for even mild depression (score of 5) as assessed by this tool (Kroenke et al., 2001). This total score was added as a predictor of pain intensity, pain unpleasantness, and emotional judgment accuracy. As it was not significant in any model, it was dropped from further analysis.

<u>Pain Ratings</u>

Orienting hypothesis. In order to test the orienting hypothesis, a repeated-measures general linear mixed model testing visual stimulus type (face, scrambled image, no image) was conducted for pain intensity, pain unpleasantness, and proportion correct. A random intercept for subjects was added to control for individual differences in pain perception and reporting. Temperature of the noxious heat pulse was added into the model to control for the rating changes that occur as a result of the three different temperatures of the heat pulses. There were no significant differences between the visual stimulus types in pain intensity (*Figure 2*), $F(2, 78) = .85$, $p=.43$, or pain unpleasantness (*Figure 3*), $F(2, 78) = 2.54$, $p=.09$. As can be seen in *Figure 4*, there was a main effect on accuracy, $F(2,78) = 3.57$, $p <.01$, such that the scrambled image trials were more consistently identified than the no face trials, $t(78) = 2.58$, $p=.03$. However, there was no difference in accuracy between the face and scrambled images or between the face and no image trials. Therefore, the results cannot be explained merely by the attentional effects of an on-setting stimulus.

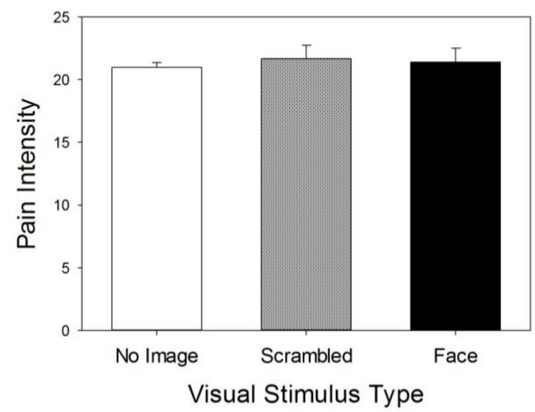

Figure 2. Pain intensity ratings by visual image type.

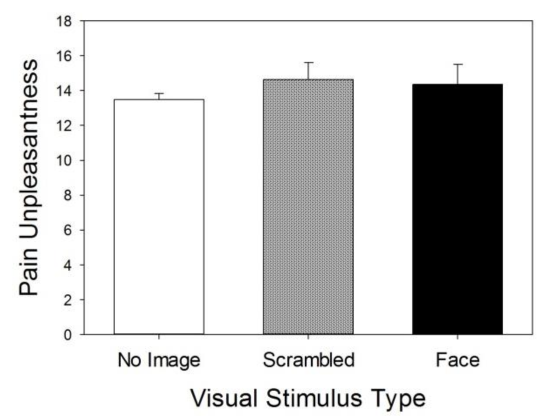

Figure 3. Pain Unpleasantness ratings by visual image type.

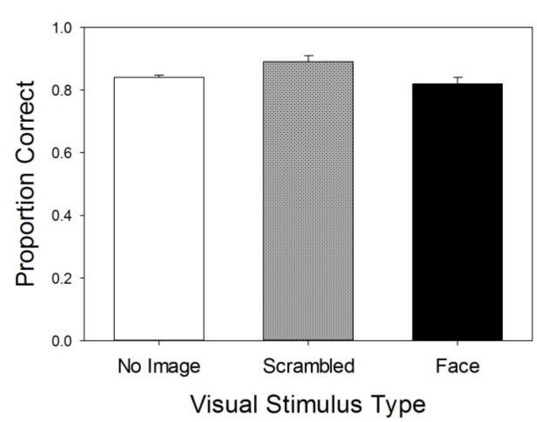

Figure 4. Proportion correct by Visual Stimulus type.

Emotion and Load*.* To test the effects of emotion, cognitive load, and their interaction, a 2 (orientation: upright, inverted) X 4 (emotion: neutral, happy, angry, fearful) repeated-measures mixed GLM was conducted for both pain components. Again, the model included a random intercept for the subjects term, as well as a term for the temperature of the noxious heat pulse.

For pain intensity, there was a significant main effect of temperature, $F(2, 78) = 1003.55$, $p<.0001$, such that both noxious temperatures were rated as significantly more painful than the below threshold temperature and the highest heat pulse was rated as significantly more painful than the lower noxious heat pulse. There was not a significant main effect of orientation, $F(1, 39) = .06$, $p=.81$, but there was a significant effect of facial expression on pain intensity ratings, $F(3,117) = 5.24$, $p=.002$ (*Figure 5*). Post-hoc testing using Tukey's adjustment shows that this main effect was due to significantly higher pain ratings during happy faces compared with neutral faces, $t(117) = 3.63$, $p=.0023$.

Pain unpleasantness (*Figure 6*) showed a very similar pattern to pain intensity, which is not surprising considering the high correlation between these two components, $r=.79$, $p<.001$. There was a main effect of temperature, $F(2, 78) = 656.45$, $p<.0001$, in that higher temperatures had significantly higher unpleasantness ratings. There was no effect of orientation, $F(1,39) = .13$, $p<.72$. There was a main effect of emotion, $F(3,117)$ = .3.35, $p<.02$, such that pain unpleasantness was significantly higher while viewing happy faces compared with neutral faces, $t(117) = 2.97$, $p=.02$.

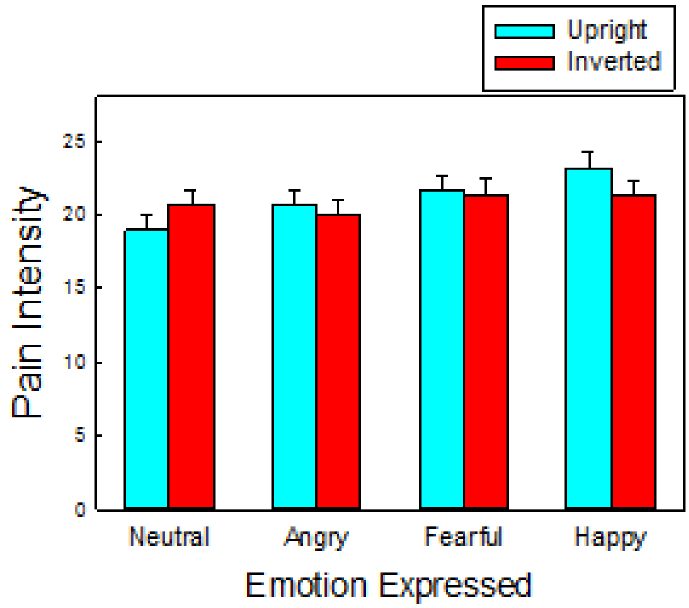

Figure 5. Pain intensity ratings for upright and inverted faces with neutral, angry, fearful, and happy expressions.

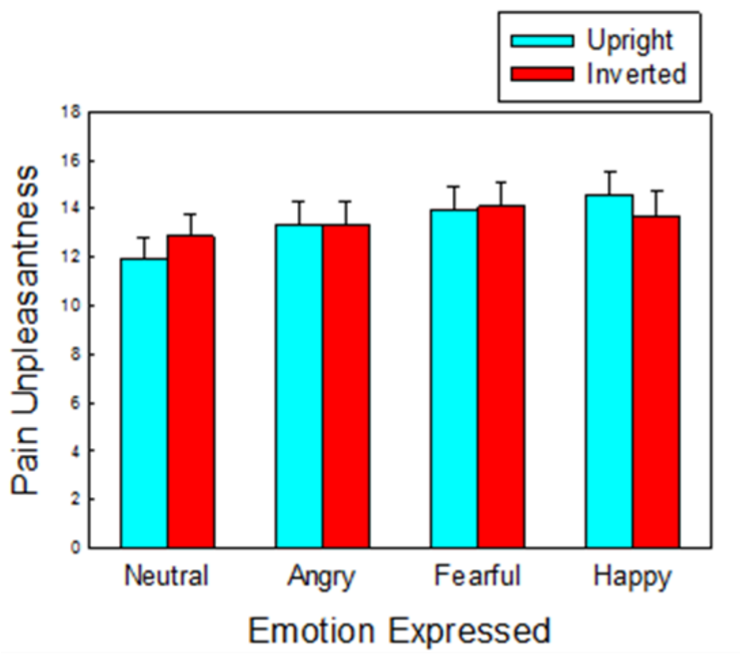

Figure 6. Pain unpleasantness ratings for upright and inverted faces with neutral, angry, fearful, and happy expressions.

Identical analysis for pain intensity and unpleasantness were conducted using only trials in which the subject correctly identified the emotion expressed in the image. None of the statistical decisions were affected.

Since there was no effect of inversion, I collapsed those categories in order to determine if the significant difference between happy faces and neutral faces was due to an increase in pain due to viewing happy faces (compared with viewing no face) or a decrease in pain when viewing neutral faces. As can be seen in *Figure 7* (pain intensity) and *Figure 8* (pain unpleasantness), this effect was due to the decrease in pain while viewing neutral faces. However, this only reached statistical significance for pain unpleasantness, $t(195) = -2.20$, $p = .03$.

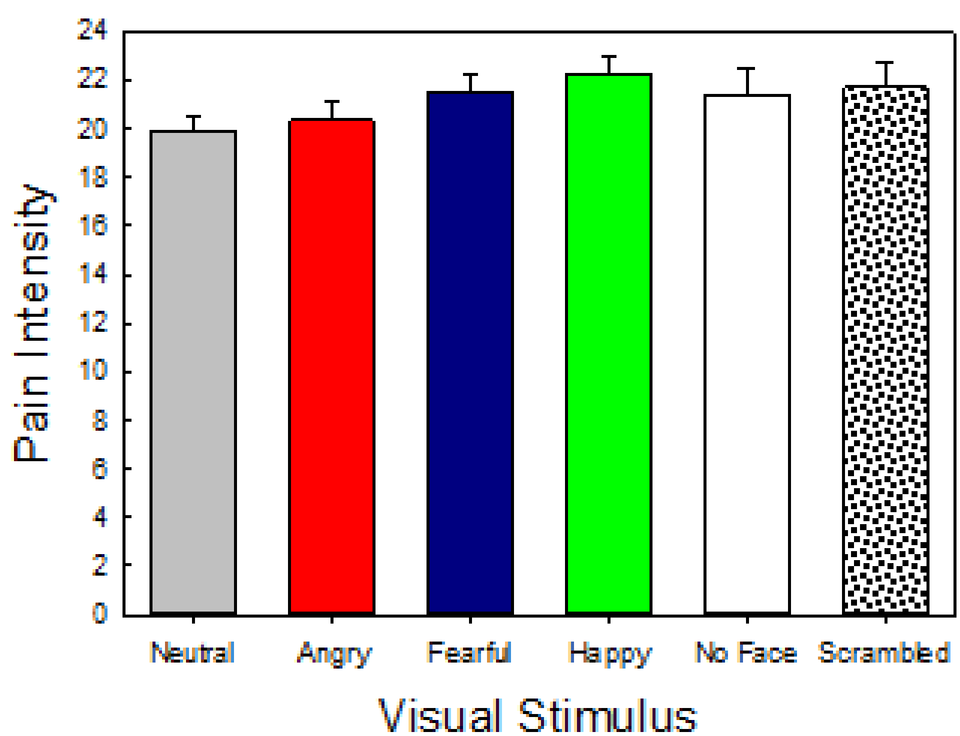

Figure 7. Pain intensity collapsed across orientation category.

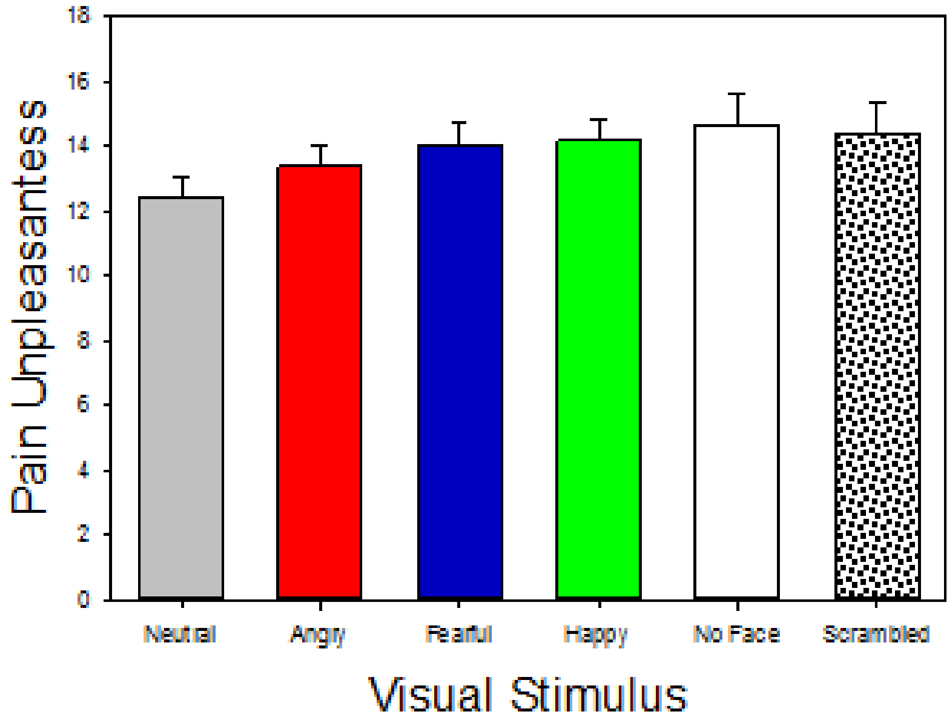

Figure 8. Pain unpleasantness collapsed across orientation category.

<u>Emotion Judgments</u>

Overall Accuracy. Accuracy data were collected and analyzed for the 4- AFC response. A 4 (emotion: neutral, happy, angry, fearful) X 2 (orientation: upright, inverted) repeated-measures mixed GLM was conducted on the accuracy of the judgment task. There was no main effect of temperature, $F(2,78) = 1.98$, $p=.14$. The significant main effects of emotion, $F(3,117) = 43.02$, $p<.0001$, and orientation, $F(1,39) = 25.10$, $p<.0001$, were qualified by an interaction between the two terms, $F(3,117) = 4.05$, $p=.009$ (*Figure 9*). For both upright and inverted faces, anger ($M=.75$, $M=.69$) had statistically lower accuracy than the three other facial expressions. However, the interaction comes from the differences in upright and inverted faces concerning the accuracies for the other three emotions. For upright faces, participants were significantly better at identifying fearful faces (*M*=.95) than neutral faces (*M*=.87), $F(3,117) = 4.05$, p=.009. There was no significant difference between fearful and neutral accuracy for inverted faces. However, happy (*M*=.92) faces were recognized with significantly greater accuracy than both fearful (*M*=.81) and neutral (*M*=.80) faces when the images were inverted.

Figure 9. Accuracy for upright and inverted faces with neutral, angry, fearful, and happy expressions.

Effect of pain on accuracy. Although the temperature of the heat pulse did not affect accuracy on a trial by trial basis, we wanted to determine if the presence of noxious heat pulses reduced overall accuracy. To test this hypothesis, we compared accuracy in the pilot study block in which faces were presented for 2s to accuracy in the main experiment (*Figure 10)*. In this way, we were able to test the differences in accuracy between-groups when pain was present in the experiment versus when it was not (pilot study). There was a significant main effect of presence of pain, with accuracy being significantly lower when pain was present (M=.84) compared to when it was not (M=.89), $F(1,66) = 7.34$, p=.009). Additionally, the presence of pain also affected the accuracy patterns across the emotion and orientation manipulations. There was no effect of orientation in the pilot experiment, but pain significantly lowered accuracy for inverted facial categorization. In terms of emotion categorization, pain had an especially negative effect on participant's ability to recognize angry faces. In the main experiment, but not the pilot, angry faces resulted in significantly less accuracy than even the neural faces.

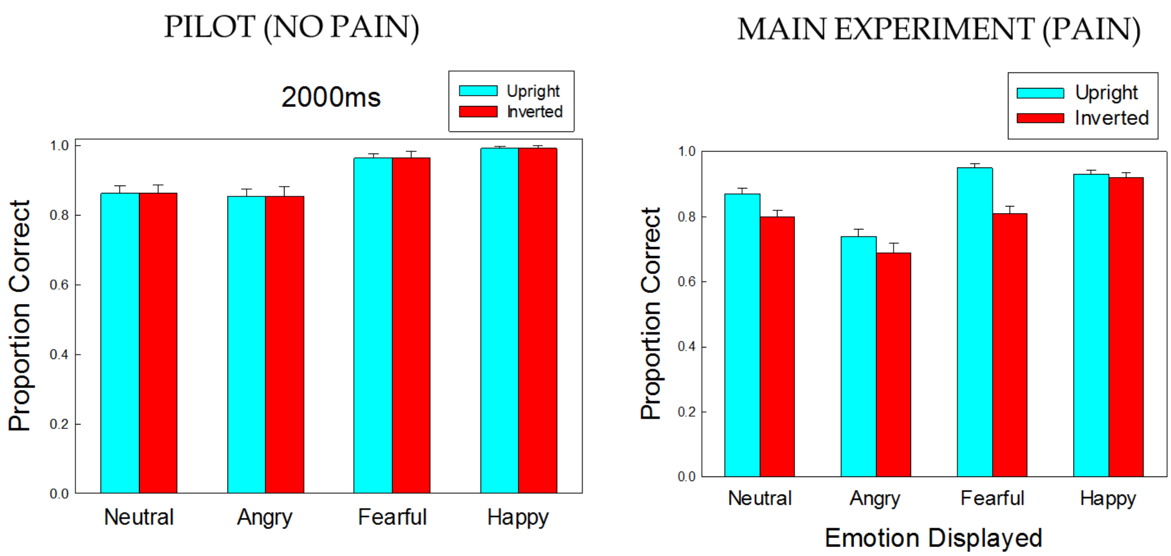

Figure 10. Comparison of pilot (no pain) with main experiment (pain) accuracy ratings.

Confusion matrices. In a forced choice task such as this, it is important to analyze the pattern of incorrect responses. The table below (*Table 1*) shows the confusion matrices for both the pilot study and the main experiment. As stated above, overall accuracy was lower for the main experiment. The main point of this table is that participants were not preferentially choosing one facial expression. The errors depend on the emotion that was displayed. For instance, in the main experiment, angry faces were often misidentified as neutral. However, the low incidence of this type of error for fearful and happy faces indicates that participants were not simply choosing the "neutral" option when they were unsure of the expression.

PILOT	Emotion Displayed (Actual)				
Emotion Decision		Neutral	Angry	Fearful	Happy
	Neutral	85	11.47	2	.6
	Angry	11.94	79.73	2.79	0
	Fearful	2.63	7.46	93.21	.4
	Happy	.40	1.34	2	99

MAIN	Emotion Displayed (Actual)				
Emotion Decision		Neutral	Angry	Fearful	Happy
	Neutral	83.67	14.2	4.62	3.88
	Angry	7.35	72.37	3.75	1.44
	Fearful	6.80	10.99	87.73	1.72
	Happy	1.50	2.29	3.32	92.53

Table 1. Confusion matrices for pilot and main experiments.

Discussion

The purpose of this experiment was to determine if face processing modulates pain perception and, if so, to determine whether that modulation is due to cognitive, emotional, or a combination of cognitive and emotional factors. In order to answer these questions, participants viewed emotional stimuli that were either high load (inverted faces) or low load (upright faces) while a series of heat pulses were applied to their volar forearm. Following each trial, ratings were given concerning the intensity and unpleasantness of the heat pulses and the participant also categorized the visual stimulus. Happy faces resulted in the highest pain ratings and also had the highest accuracy in the emotion categorization task. We conclude that viewing emotional faces does not cause an emotional reaction in the participant that is strong enough to modulate pain processing. However, the cognitive load associated with identifying the emotional expression contained on each face is sufficient to reduce noxious processing by means of distraction.

Image type

Previous experiments have been equivocal about the effects of facial processing on pain perception. One possible reason for the discrepancies in the results is the differences in experimental design. Several of the experiments (Yoshino et al., 2010, 2012) did not have a no-face condition, while others had no control for an on-setting visual stimulus (Senkowski et al.; Reicherts et al.). This lack of control trials makes it difficult to determine whether the results were due to the stimuli themselves or are artifacts of the experimental design. In the present study, we included both no-face trials and trials with a non-face, on-setting visual stimulus in order to control for these experimental effects.

In order to exclude the possibility that the on-setting of the stimuli led to orienting or distracting effects, ANOVAs were conducted to determine the effect of visual stimulus type (Face, Scrambled Image, No Stimulus) on pain intensity, pain unpleasantness, and accuracy. Although there was a significant difference in accuracy between scrambled images and no-face trials, no other tests were significant. The lack of controls cannot explain the discrepancy in findings between previous studies or the results of the current studies, so we must look elsewhere.

Upright vs Inverted faces

The seminal paper on the face inversion effect (FIE; Yin, 1969) and many studies since (Valentine, 1988; Lamy et al., 2008) have found accuracy and speed decrements due to inversion. Therefore, in our experiment, image orientation was manipulated in an attempt to manipulate cognitive load. Indeed, overall accuracy in the categorization task was significantly lower when the face was inverted than when the face was upright. However, there was no significant difference in pain ratings between these conditions.

In this experiment, accuracy is a proxy for cognitive load. That is, a difficult task will have a higher cognitive load and thus lower accuracy than an easy task. In general, pain ratings are reduced when there is a concurrent task, indicating that there is a common pool of resources for noxious and cognitive processing. Due to the differences in cognitive load between upright and inverted faces, we expected, but did not find, lower pain ratings after trials with inverted faces.

One possible explanation for this result is that the load manipulation between upright and inverted faces was not strong enough. Distraction effects in pain are not universal, but depend on characteristics of the distractor, especially difficulty. In order for a task to reduce pain, it must be much more taxing that the comparison condition (Buhle & Wager, 2010). Although accuracy was significantly lower for inverted versus upright faces, the numerical difference was small, and accuracy for the inverted faces was still quite high. This may be because inversion slows, but does not eradicate our ability to identify and react to the emotion on a human face (Lipp et al., 2009; Bannerman et al., 2008; Lamy et al., 2008). One of the theories concerning the FIE is that upright faces are processed holistically while inverted faces are processed piecewise (e.g. Farrah, 1995). Calvo and Marrero (2009) present strong evidence that emotional identification relies primarily on detecting salient features (like a wide, white spot in a smiling face). This strategy is effective regardless of whether the face is upright or inverted because there is no need to piece together all the pieces of the inverted face. For this reason, the difficulty of the categorization task depended on both orientation and emotion. Certain expressions, such as happy faces, have more salient features that allow for feature-based identification, which negates the effect of inversion. Inversion effects in this experiment were only observed for fearful and neutral images. Load was determined not only by orientation, but also by facial expression; therefore the emotional effects must also be considered. Therefore, the cognitive load required to glean emotional information from inverted faces is not high enough to negatively impact pain processing compared to emotional identification of upright faces.

Emotional versus neutral images

Although there was no main effect of orientation on pain intensity and unpleasantness ratings, there was a main effect of emotion. Although there was an overall increase in pain ratings after emotional compared with neutral faces, the only comparison that survived adjustments for multiple comparisons was happy versus neutral. Our results fit well into the literature, but our study suggests a different explanation behind this pattern.

Cognitive effects. The present findings are most similar to those of Senkowski et al., who found that emotional faces increased pain ratings compared to neutral faces. The authors concluded that these emotion-general increases in pain ratings were due to increased processing in the somatosensory cortices. In light of our findings, however, Senkowski's study could be explained by cognitive load and not pre-activation of areas responsible for pain processing. Although participants were not required to overtly characterize the face, emotional identification of faces is a socially and evolutionarily important task that we complete each time we see a face. For neutral faces, which are more ambiguous and harder to categorize, there were fewer resources available for pain processing (compared with the easier to identify emotions) and thus pain ratings were reduced. This explanation, that cognitive and not emotional factors, are associated with pain modulations by face processing, also fits with the findings of Reicherts (2013). In that experiment, videos were presented in which a face changed gradually into each facial expression. All videos, regardless of facial expression, decreased pain compared with the no video condition. As in our study, the load of processing the faces, and not the valence, impacted pain ratings.

Emotional effects. On the other hand, a third study on this topic cannot be explained by a cognitive difference between the conditions. Yoshino et al. (2010, 2012) found an emotion specific effect such that sad faces compared with neutral faces, increased pain ratings. This experiment has one very important difference compared with the present study, as well as with Senkowski and Reicherts. Compared with those experiments, the face stimuli were on screen between 4400ms and 3000ms longer in Yoshino's studies. Longer presentation times of the facial expressions, in contrast to the early and short presentation of the noxious stimulus (1000ms) may have given the participant time to focus on and vicariously experience the emotion of the face. Viewing unpleasant faces for several seconds after pain cessation would induce a negative affect in the participant, which would increase pain ratings in turn. This emotional congruency, or motivational priming, effect has much support in the literature (Meagher et al., 2001).

The results of our experiment cannot be explained in terms of emotion induction in the participant since the pleasant faces resulted in the most pain, a result that is in direct opposition to the motivational priming theory. Why is it that in our experiment, as well as in Senkowski and Reicherts, there were no valence specific effects on pain? One possibility is that the relative time courses of the noxious and facial stimuli were such that the faces were not able to change participants' emotional state in time to affect their judgement of unrelated, but concurrent stimuli. Viewing facial expressions of strangers, even at the threshold of conscious perception, has been shown to influence pleasantness ratings of unrelated, non-noxious stimuli (Payne et al., 2010; Blaison et al., 2012). However, in order to modulate the experience of pain, which is important for survival and thus a processing priority, the mood induction must be overt and temporally longer than the noxious stimulus. Godinho, Magnin, Frot, Perchet and Garcia-Larrea (2006) found that emotional modulation of pain perception occurred at a later stage (270ms after stimulation) than the sensory processing of the pain itself (20-150ms). Attentional manipulations are capable of modifying those SEPs (sensory evoked potentials) much more quickly (40-150 ms). Taken together, these results suggest that distraction reduces the ability to generate the basic pain sensation, but emotional modulation (which requires more time and processing) influences our memory for the noxious stimulus. Concerning the present results, participants were heavily distracted by the ambiguous neutral images and could not devote as many resources to processing the following noxious stimulus; this decreased both components of pain. The emotional faces were either not strong enough or not presented for long enough to modulate the mood of the participant in valence specific ways.

Another possibility is that participants experienced social pain due to perceiving a stranger's happiness during their own pain. Social pain, or the feelings of social rejection and exclusion, shares some of the same neural substrates (Eisenberger, 2012) as physical pain. Mild social pain can therefore increase perceptions of physical pain (Bernstein & Claypool, 2011). Conversely, the negative and neutral expressions may have been interpreted as empathetic or sympathetic, and thus did not increase ratings, but lead to lower pain ratings instead.

Effects of pain on emotion identification and categorization

On a trial by trial basis, there was no effect of pain levels on task accuracy in the main experiment. This finding is not surprising given the results of Wieser et al. (2012), in which emotional discrimination of faces was not impaired on pain trials compared to non-pain trials. Negative impacts on cognitive processing have been found for both concurrent laboratory (Buhle & Wager, 2010) and chronic (Berryman et al., 2013) pain. We do find an accuracy reduction due to the presence of pain in the experiment overall, compared to the innocuous pilot experiment. Participants were significantly more accurate in Block 3 (M=.87) than Block 1 (M=.82), $t(71) = 2.88$, $p = .01$, indicating that they became better at the task with practice over the course of the main experiment. Even at their best in Block 3, however, accuracy was still much lower than in the pilot task. This finding suggests two things. First, recognizing facial expressions requires cognitive resources and secondly, those resources share a common pool with those required to process pain.

It is important to note that, although emotion recognition was not impaired, the ability to empathize with or be influenced by those facial expressions might have been reduced by the presence and amount of pain. Gerdes et al. (2012) found that pain selectively inhibited one's ability to mimic happy faces. It is possible that participants were able to recognize the emotion on the face, but their first person pain made it impossible for them to be made happy by a happy stranger.

Limitations and future directions

Our results suggest a cognitive, not emotional, cause for pain modulation due to face processing. There are several limitations to this study design that future research should address in order to solidify our conclusions. We found that the difficulty of identifying a neutral face, compared with more straightforward facial expressions, could be the cause for pain reductions. Future experiments should vary the difficulty of the task that requires face processing across neutral and emotional faces in order to further test the contributions of load and valence.

We conclude that our emotional stimuli did not influence the mood of the participant. As stated above, however, it could be that the stimuli did influence mood, but in a situational and not general way. In other words, it could be that happy faces were interpreted as making fun of or being unsympathetic to the hurting participant. Pain could be blocking the participant's ability to understand or empathize with a happy face. In order to rule out this emotional explanation, future studies should not only ask the participant to make judgments about the image, but also to indicate how the image makes them feel. Ratings of personal reaction to those images would allow us to determine if or how viewing emotional faces of strangers influences pain ratings through mood induction.

Along those lines, it may be that the experimental design employed by Senkowski et al., Reicherts et al., and our research team were not optimized to induce mood changes. Future studies should vary the length of time faces are presented. Such a manipulation would target both attentional load (very short presentation times would be more difficult to identify) and ability to induce mood changes (very long presentations would be more effective).

Conclusion

Although both valence and load of concurrent stimuli are capable of modulating pain, it is important in an experimental design to consider the relative effects of each. Viewing emotional faces in order to make categorization judgments modulates pain, possibly due to cognitive load instead of facial expression.

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